**Appendices**

**Appendix 1 General characteristics of included studies of the literature review and the grey literature review**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **First author (publication year)** | **Title of the article** | **Healthcare setting** | **Country** | **Type of study** |
| Li (2015) | Applying an evidence-based approach to managing alarm Safety: A university health network case study | Intensive care unit | Canada | Case study |
| Solsona (2001) | Are auditory warnings in the intensive care unit properly adjusted? | Intensive care unit | Spain | Before after assessment, case control |
| Seagull (2000) | Auditory alarms: From alerting to informing | Anaesthesia, USA | USA | Observation of eye tracking in real and simulated cases |
| Ketko (2015) | Balancing the tension between hyperoxia prevention and alarm fatigue in the NICU | Neonatal intensive care unit | USA | Quality improvement work, case control |
| Rejab (2014) | Incremental real time support vector machines for health monitoring system | Intensive care unit | Tunisia | Modelling |
| Bai (2015) | Integrating monitor alarms with laboratory test results to enhance patient deteriorations prediction | Hospital | USA | Experimental design |
| Siebig (2010) | Intensive care unit alarms—How many do we need? | Intensive care unit | Germany | Prospective, observational, clinical study |
| Khuntia (2015) | Juggling digitalization and technostress : The case of alert fatigues in the patient care system implementation | Patient room | USA | Case study, ethnographic approach |
| Vannicola (2007) | Medical signal processing in the ICU | Intensive care unit | USA | Modelling |
| Cvach (2012) | Monitor Alarm Fatigue: An integrative review |  |  | Literature review |
| Graham, (2010) | Monitor alarm fatigue: Standardizing use of physiological monitors and decreasing nuisance alarms | Medical progressive care unit | USA | Case study, before after intervention |
| Whalen (2014) | Novel approach to cardiac alarm management on telemetry units | General medical surgical unit | USA | Case study |
| Bennett, (2012) | PT-SAFE: A software tool for development and annunciation of medical audible alarms | Operating room simulated environment | USA | Software tool development |
| Ursprung (2005) | Real time patient safety audits: Improving safety every day | Intensive care unit | USA | Pilot, intervention study |
| Zhang (2007) | Real-time development of patient-specific alarm algorithms for critical care | Paediatric intensive care unit | USA | Alarm algorithm improvement |
| Zhang (2007) | Real-time evaluation of patient monitoring algorithms for critical care at the bedside | Paediatric intensive care unit | USA | Alarm algorithm improvement |
| Sun (2014) | Reducing ECG alarm fatigue based on SQI analysis | Intensive care unit | China | Computer science analysis |
| Stevens (2012) | Smart alarms: Multivariate medical alarm integration for post CABG surgery patients | Intensive care unit | USA | Alarm algorithm improvement |
| Paine (2016) | Systematic review of physiologic monitor alarm characteristics and pragmatic interventions to reduce alarm frequency |  |  | Systematic literature review |
| Bennett (2011) | Urgency analysis of audible alarms in the operating room | Intraoperative environment | USA | Experimental |
| Cvach (2014) | Use of pagers with an alarm escalation system to reduce cardiac monitor alarm signals | Surgical progressive care units | USA | Before after intervention study |
| Vockley (2012) | Safety innovations - Recommendations for alarm signal standardization and more innovation - The Christiania care health system experience | 913 bed Christiania hospital, 241 bed hospital in Wilmington | USA | Quality improvement |
| The AAMI and HTSI (AAMI Foundation 2012) | Safety innovation - Using data to drive alarm system improvement efforts - The Johns Hopkins Hospital experience | Johns Hopkins Hospital | USA | Quality improvement |
| Allen (2012) | Safety innovations - Simple solutions for improving patient safety in cardiac monitoring - Eight critical elements to monitor alarm competency - University of Pittsburgh Medical Center (UPMC); Presbyterian Hospital | Pittsburgh Medical Center (UPMC); Presbyterian Hospital | USA | Quality improvement |
| Talley, (2013) | Safety innovations - Cardiopulmonary monitors and clinically significant events in critically ill children - Children's National Medical Center. | Paediatric intensive care unit | USA | Quality improvement |
| The AAMI and HTSI (AAMI Foundation 2013) | Safety innovations - Safeguarding patients with surveillance monitoring - The Dartmouth-Hitchcock Medical Center experience | The Dartmouth-Hitchcock Medical Center Experience | USA | Quality improvement |
| Lipschultz (2014) | Safety innovations - Clinical practice changes associated with alarm standardization - The Boston Medical Center experience | Boston medical 496 bed medical center | USA | Quality improvement |
| Epstein (2016) | Safety innovations - Fighting alarm fatigue with data-driven interventions - The NCH Healthcare Device Eco-System experience | NCH Healthcare System at Naples, Florida, and two hospitals, including the NCH physician group in 17 locations within the region | USA | Quality improvement |

**Appendix 2 Interview questions**

1. What are the main problems with alarm hazards in healthcare based on your experiences?
2. What could be the solutions to the problems and why?
3. Have you been involved in any improvement work related to alarm safety? Could you tell more about it?
   1. What was the problem aiming to be solved?
   2. How was the intervention defined?
   3. How was the theory of change defined?
   4. How did you know that the change was an improvement?
   5. Is there any published materials based on the improvement work?
   6. Is there another person that you would feel relevant to contact regarding the improvement work?
4. Could you suggest other people that would be interested being involved in this work?
5. Any other comments?

**Appendix 3 Interviewees’ occupations and country**

|  |  |  |
| --- | --- | --- |
| **Country** | **Medical doctors** | **Nurses** |
| Austria | 1 | 0 |
| Australia | 1 | 2 |
| France | 1 | 0 |
| Indonesia | 3 | 0 |
| Italy | 1 | 0 |
| Norway | 0 | 1 |
| Slovenia | 4 | 2 |
| The Netherlands | 1 | 0 |
| The UK | 0 | 2 |
| USA | 0 | 7 |
| **TOTAL** | **12** | **14** |

**Appendix 4 Brief description of the included alarm-related standards**

* IEC 60601-1-8 is an international standard that discusses general requirements for basic safety and essential performance for alarm systems in medical electrical equipment and medical electrical system, and to provide guidance for their application. Specifically, the Collateral Standard provides general requirements, tests and guidance for alarm systems in medical electrical equipment and systems.
* IEC 62366-1:2015 is another international standard that discusses a process for manufacturers of medical devices to analyse, specify, develop and evaluate the usability of their medical devices in relation to safety. The standard discusses alarm systems very briefly.
* ANSI/AAMI HE 75:2009/®2013 is an American national standard that provides comprehensive guidance covering specific human factors topics related to the design of medical devices such as user-friendliness of design, managing risks of use errors, and usability testing. This standard also provides guidance on alarm design using human factors principles and considers specific requirements from IEC 60601-1-8 standard.

**Appendix 5 Identified improvement elements of the literature and grey literature reviews**

| **First author (publication year)** | **Title of the article** | **Themes of improvement elements** | | | | | | | | |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Alarm assessment and evaluation | Alarm configuration | Alarm design | Alarm inventory and prioritisation | Alarm protocols and standard procedures | Machine learning | Multidisciplinary teamwork | Training and education | Sharing and learning | Alarm safety culture |
| Li (2015) | Applying an Evidence-based Approach to Managing Alarm Safety: A University Health Network Case Study |  |  |  | ✓ | ✓ |  |  | ✓ |  | ✓ |
| Solsona (2001) | Are auditory warnings in the intensive care unit properly adjusted? |  | ✓ |  |  |  |  |  |  |  | ✓ |
| Seagull (2000) | Auditory alarms: from alerting to informing |  |  | ✓ |  |  |  |  |  |  |  |
| Ketko (2015) | Balancing the Tension Between Hyperoxia Prevention and Alarm Fatigue in the NICU |  | ✓ |  |  | ✓ | ✓ | ✓ |  |  |  |
| Rejab (2014) | Incremental Real Time Support Vector Machines for Health Monitoring System |  |  |  |  |  | ✓ |  |  |  |  |
| Bai (2015) | Integrating monitor alarms with laboratory test results to enhance patient deteriorations prediction |  |  |  |  |  | ✓ |  |  |  |  |
| Siebig (2010) | Intensive care unit alarms—How many do we need? |  |  |  |  |  | ✓ |  | ✓ |  |  |
| Khuntia (2015) | Juggling digitalization and technostress : the case of alert fatigues in the patient care system implementation | ✓ | ✓ |  |  |  |  |  | ✓ |  |  |
| Vannicola (2007) | Medical signal processing in the ICU |  |  |  |  |  | ✓ |  |  |  |  |
| Cvach (2012) | Monitor Alarm Fatigue An integrative Review | ✓ | ✓ | ✓ |  | ✓ | ✓ | ✓ | ✓ |  |  |
| Graham, (2010) | Monitor alarm fatigue: Standardizing use of physiological monitors and decreasing nuisance alarms | ✓ | ✓ |  |  | ✓ | ✓ | ✓ | ✓ |  |  |
| Whalen (2014) | Novel approach to cardiac alarm management on telemetry units | ✓ | ✓ |  |  | ✓ |  | ✓ | ✓ |  |  |
| Bennett, (2012) | PT-SAFE: A Software Tool for Development and Annunciation of Medical Audible Alarms | ✓ |  |  |  |  | ✓ |  |  |  |  |
| Ursprung (2005) | Real time patient safety audits: improving safety every day | ✓ |  |  |  |  |  |  |  |  | ✓ |
| Zhang (2007) | Real-Time Development of Patient-Specific Alarm Algorithms for Critical Care |  |  |  |  |  | ✓ |  |  |  |  |
| Zhang (2007) | Real-Time Evaluation of Patient Monitoring Algorithms for Critical Care at the Bedside |  |  |  |  |  | ✓ |  |  |  |  |
| Sun (2014) | Reducing ECG Alarm Fatigue Based on SQI Analysis |  |  |  |  |  | ✓ |  |  |  |  |
| Stevens (2012) | Smart Alarms: Multivariate Medical Alarm Integration for Post CABG Surgery Patients |  |  |  |  |  | ✓ |  |  |  |  |
| Paine (2016) | Systematic Review of Physiologic Monitor Alarm Characteristics and Pragmatic Interventions to Reduce Alarm Frequency |  | ✓ |  |  | ✓ | ✓ |  |  |  |  |
| Bennett (2011) | Urgency analysis of audible alarms in the operating room |  |  | ✓ |  |  |  |  |  |  |  |
| Cvach (2014) | Use of Pagers with an alarm escalation system to reduce cardiac monitor alarm signals |  |  |  |  |  | ✓ |  |  |  |  |
| Vockley (2012) | Safety Innovations - Recommendations for alarm signal standardization and more innovation - The Christiania Care Health System Experience | ✓ |  |  |  |  | ✓ | ✓ | ✓ | ✓ | ✓ |
| AAMI Foundation (2012) | Safety Innovation - Using Data to Drive Alarm System Improvement Efforts - The Johns Hopkins Hospital Experience | ✓ | ✓ |  | ✓ | ✓ | ✓ | ✓ | ✓ |  | ✓ |
| Allen (2012) | Safety Innovations - Simple Solutions for Improving Patient Safety In Cardiac Monitoring - Eight Critical Elements to Monitor Alarm Competency - University of Pittsburgh Medical Center (UPMC); Presbyterian Hospital | ✓ | ✓ |  | ✓ | ✓ |  |  | ✓ | ✓ |  |
| Talley, (2013) | Safety Innovations - Cardiopulmonary Monitors And Clinically Significant Events in Critically Ill Children - Children's National Medical Center. | ✓ | ✓ |  | ✓ |  |  | ✓ |  |  |  |
| AAMI Foundation (2013) | Safety Innovations - Safeguarding Patients With Surveillance Monitoring - The Dartmouth-Hitchcock Medical Center Experience |  | ✓ |  |  |  |  | ✓ | ✓ |  |  |
| Lipschultz (2014) | Safety Innovations - Clinical Practice Changes Associated with Alarm Standardization - The Boston Medical Center Experience |  | ✓ |  |  | ✓ |  | ✓ | ✓ |  | ✓ |
| Epstein (2016) | Safety Innovations - Fighting Alarm Fatigue with Data-Driven Interventions - The NCH Healthcare Device Eco-System Experience | ✓ |  | ✓ |  | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

**Appendix 6 Overview of alarm problems identified in the literature and grey literature reviews and interviews**

|  |  |  |
| --- | --- | --- |
| **Themes of alarm problems** | **Identified in the literature and grey literature reviews** | **Identified in the interviews** |
| **Alarm assessment and evaluation** | The lack of assessment and evaluation of newly adopted alarming devices and how alarms actually work in practice and function with other alarms in a clinical environment provided healthcare staff with minimal information and baseline data to direct improvement. In addition, different alarm defaults from different manufacturers were suggested to cause difficulties in reconfiguring alarms to fit a clinical environment. Consequently, staff responses to alarms were variable as well as how staff dealt with errors related to equipment failure. | Lack of assessment and/or evaluation on alarm safety interventions and alarms interactions in a clinical environment were mentioned by interviewees as alarm problems as well as the impact of cacophony of alarms on the well-being of staff and patients. An example of a consequence of the lack of assessment and evaluation on alarm safety intervention was the fact that alarm intervention might create new problems. For example, an interviewee mentioned that as an intervention, bed side alarms were connected to nurses’ mobile phones to make sure that the nurses were informed when alarms went off. However, nurses’ phones were also used to receive phone calls from other healthcare staff such as doctors. As a result, nurses’ mobile phones were ringing all the time, creating alarm fatigue. |
| **Alarm configuration** | Literature showed that default alarm settings usually resulted in excessive false alarms that desensitized staff as the result of (1) the high sensitivity and low specificity philosophy in alarm default settings, (2) generalization of alarms to a wide range of patient conditions rather than patient-specific conditions, (3) patient or staff manipulation, (4) the lack of agreement or understanding in setting appropriate alarm limits and levels, (5) self-resetting alarm default settings, and (6) overly narrow alarm thresholds. | Interviewees mentioned that there was a lack of protocols to standardise or modify the settings of medical devices from different manufacturers such as alarm parameters and volume. In addition, changing alarm parameters was perceived as not user-friendly and every device had its own default settings. As a result, alarms were beeping all the time, including during alarm manipulation and when patients moved. An excessive amount of false positive alarms was perceived as disturbing. |
| **Alarm design** | Manufacturers of alarming medical devices have focused on developing safe, functional and user-friendly alarms. Nevertheless, the literature showed that there was still room for improvement. For example, true alarms were often perceived as uninformative and confusing, and the fact that urgency alarm melodies were not standardised led to alarm learnability challenges and longer response time. Alarm system designs of different medical devices were not usually standardised and changing alarm settings was neither perceived as intuitive nor user-friendly. The challenges in integrating different alarm systems included managing inconsistencies in alarm system functions (e.g. alerting, sounds, providing information, suggesting action, directing action, taking action) and characteristics (e.g. terminology, information provided, integration, degree of processing, prioritization) across medical devices. | It was mentioned that alarm melodies and notification could not always be discriminated by their urgency or severity levels for different patient conditions. Consequently, it was not always clear what each alarm meant especially when alarms were beeping simultaneously all the time. |
| **Alarm inventory and prioritisation** | Literature pinpointed that sources of alarms were not always successfully identified by staff, increasing the risk of ignorance of critically clinical alarms. In addition, it was suggested that many alarms conditions were duplicated, causing unnecessary increase of alarm signals. Accordingly, prioritising actionable alarm signals was suggested as an important solution to reduce excessive alarm signals by conducting an alarm inventory to gather data such as the number of alarms per bed, their types and duration, and documenting baseline alarm conditions and signals. Prioritisation could also mean subordinating, or if necessary, eliminating lower-priority warning or advisory alarm conditions to, for example, visual signals or vibration. | It was mentioned that a lack of agreed accountability for setting alarms was a problem that could lead to variable staff behaviours. An interviewee provided an example that when alarms were going off simultaneously, it made prioritisation for staff action more difficult especially for a clinical environment such as at triage. |
| **Alarm protocols and standard procedures** | Ten studies highlighted the fact that lack of alarm protocols, agreements, and standard procedures on how to deal with alarms led to variable staff behaviours towards alarms and challenges in the workflow. In establishing alarm protocols and standard procedures, the literature suggests different focus areas. These include establishing protocols to set patient-specific alarms, documenting alarm parameters in the medical records to improve alarm adjustment compliance, agreeing on procedures to pause or silence alarms to remove unnecessary alarms especially during patient or staff manipulation, standard procedures to ensure safe alarm management and response, adjusting staffing models that consider alarm response time as a primary task, reinforcing proper skin preparation for ECG leads and electrodes and daily replacement electrode to ensure proper signal acquisition and reduce artefacts, and ensuring accountability of all alarms in an environment. Establishing an evaluation protocol was seen as necessary to measure the effect of the established alarm protocols or standard procedures. | Interviewees mentioned several alarm problems related to alarm protocols and standard procedures. It was mentioned that alarm limits were often set inappropriately, either too narrow or too wide, causing an excessive amount of false alarms. This was mentioned as a result of a lack of alarm protocols to standardise alarm settings. In addition, changing alarm settings was perceived as complicated and not user-friendly, making staff reluctant to do that. This was linked to a lack of agreed accountability to deal with alarm problems, resulting in variable staff behaviours in dealing with alarm problems. |
| **Machine learning** | Excessive false alarms were reported by the studies as the result of a wide variety of causes related to the technical aspect of alarm systems. For example, alarm systems generally lacked the capability to correlate physiological patient data with clinical events, or to adapt to individual patient characteristics that did not fit the population models. Default alarm thresholds were usually used for and generalised to all patients in a unit, causing many false alarms. False alarms were also caused by alarm systems that usually only considered one vital sign exceeding certain threshold instead of multiple parameters, as well as alarm default settings with high sensitivity and low specificity that were easily triggered by, for example, patient motions, poor physical contact between skin and sensors, or patient manipulation. Excessive alarms were usually also due to redundant alarms coming from multiple alarm systems which were not integrated or centralised. Finally, when alarms were true and clinically important, they were not always heard by responsible staff who were mostly mobile, especially those working in spacious clinical environments with long hallways, private rooms and multiple nursing stations. | Interviewees mentioned that clinicians did not always respond to alarms due to an excessive amount of alarms that desensitising clinicians and alarms were not necessarily centralised. In addition, alarms were said to be too sensitive and too frequent. An interviewee mentioned that a nurse might have to deal with approximately 1000 alarms per shift. |
| **Multidisciplinary teamwork** | Studies in our literature review pinpointed that healthcare might be lacking understanding and conformity on how to tackle excessive alarm frequency in different clinical environments. This required a multidisciplinary approach to cover human, technical and organisational factors. Therefore, forming a multidisciplinary team to tackle alarm problems was named as being crucial for managing alarm systems. The studies suggested that the multidisciplinary team could consist of managers, frontline staff, clinical engineers, biomedical technicians, information technology and information system experts, patient safety experts, researchers, human factors engineers, administrative and facility staff, and even representatives from manufacturers of alarming medical devices. Representation from all environments where alarms were located was crucial because different environments were likely to need different solutions. | Interviewees mentioned that a lack of protocols and standardisation and agreement on alarm settings, and the fact that alarms were usually set too sensitive and thus alarms beeped too frequent, required interdisciplinary planning to work together to solve alarm problems. |
| **Training and education** | Literature suggests that there was a lack of or limited training for alarm end-users around alarm systems and alarm safety in, for example, utilising alarming devices for patient-specific conditions, reducing false alarms without risking missed clinically important alarms, or dealing with non-standardised, non-patient specific alarms. A quality improvement study pinpointed the importance of delivering training in a timely manner, in this study, for newly installed alarming medical devices so that staff would be allowed to become accustomed to the auditory alarm signals of the devices. Several studies included training and education programmes in alarm intervention and suggested the programmes to be both initial and ongoing to address staff needs in dealing with alarming medical devices in the clinical environment where the devices were used. | It was mentioned that staff were usually not trained sufficiently on how to individualise or modify alarm settings, or staff did not receive any training on dealing with alarms during their formal training. Staff were usually also overworked and there was no systematic training available to them to deal with alarms. Consequently, staff did not always feel responsible or qualified to take action to deal with alarm problems such as how to set appropriate alarm parameters for different patients. |
| **Sharing and learning** | Limited knowledge around alarm systems, technologies, policies, protocols and vendors |  |
| **Alarm safety culture** | Not reported |  |

**Appendix 7 Identified improvement elements of the interviews by interviewees’ occupation and country**

| **Occupation** | **Country** | **Themes of improvement elements** | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Alarm assessment and evaluation | Alarm configuration | Alarm design | Alarm inventory and prioritisation | Alarm protocols and standard procedures | Machine learning | Multi-disciplinary teamwork | Alarm training and education | Alarm safety culture |
| Medical doctor | Austria |  |  |  |  | ✓ |  |  |  | ✓ |
| Medical doctor | Australia |  |  | ✓ |  | ✓ |  |  |  |  |
| Nurse | Australia |  |  |  |  |  |  |  | ✓ |  |
| Nurse | Australia | ✓ |  |  | ✓ |  |  |  | ✓ |  |
| Medical doctor | France |  | ✓ |  |  |  |  |  |  |  |
| Medical doctor | Indonesia |  |  |  |  |  |  | ✓ |  |  |
| Medical doctor | Indonesia |  |  | ✓ |  | ✓ |  |  | ✓ |  |
| Medical doctor | Indonesia |  |  |  |  |  |  | ✓ |  |  |
| Medical doctor | Italy |  |  |  |  | ✓ |  |  |  |  |
| Nurse | Norway | ✓ |  |  |  |  |  |  |  |  |
| Medical doctor | Slovenia |  |  |  | ✓ |  | ✓ |  |  |  |
| Medical doctor | Slovenia |  |  |  |  |  | ✓ |  |  |  |
| Medical doctor | Slovenia |  | ✓ | ✓ |  | ✓ |  |  | ✓ |  |
| Medical doctor | Slovenia |  |  | ✓ |  |  |  |  |  |  |
| Nurse | Slovenia |  | ✓ |  |  |  |  |  |  |  |
| Nurse | Slovenia | ✓ | ✓ |  |  |  |  |  |  |  |
| Medical doctor | The Netherlands |  |  | ✓ | ✓ |  | ✓ |  |  |  |
| Nurse | UK |  | ✓ |  |  | ✓ |  |  | ✓ |  |
| Nurse | UK | ✓ |  |  |  |  |  |  | ✓ |  |
| Nurse | USA |  | ✓ |  | ✓ | ✓ |  | ✓ |  |  |
| Nurse | USA |  | ✓ |  |  |  |  |  |  |  |
| Nurse | USA |  |  |  |  | ✓ |  |  |  |  |
| Nurse | USA |  |  |  |  |  | ✓ |  | ✓ |  |
| Nurse | USA |  | ✓ |  |  |  |  |  |  |  |
| Nurse | USA |  |  |  |  |  | ✓ | ✓ |  |  |
| Nurse | USA | ✓ | ✓ |  |  | ✓ |  | ✓ | ✓ |  |

**Appendix 8 Example content of alarm-related standards by theme and sub-theme of the improvement elements**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Themes of alarm improvement elements** | **Sub-themes** | **IEC 60601-1-8** | **IEC 62366-1** | **ANSI/AAMI HEF75:2009/®2013** |
| Alarm design | Alarm condition list |  |  | check-mark-13x13-th.png (100×100) |
| Alarm configuration |  |  | check-mark-13x13-th.png (100×100)  E.g. Adjustable alarm limits should be storable, but the device should clearly indicate when the limits have altered from factory settings (15.3.7).  E.g. When limits are altered from factory settings, it should be easy to return them to the default settings (15.3.7). |
| Alarm limits | check-mark-13x13-th.png (100×100) |  |  |
| Alarm presets | check-mark-13x13-th.png (100×100) |  |  |
| Attended-use model |  |  | check-mark-13x13-th.png (100×100) |
| Auditory signals | check-mark-13x13-th.png (100×100)  E.g. Priority encoded (higher priority auditory alarms shall convey a higher level of urgency than medium, and medium higher than low priority alarm condition) (6.3.3.1). | check-mark-13x13-th.png (100×100)  E.g. The medical device shall be capable of producing an auditory alarm signal with a sound pressure level adjustable over the range of 45dBA to 80 dBA when measured at 1 m from the front of the medical device (3.28). | check-mark-13x13-th.png (100×100)  E.g. Can be heard above the background noise and/or other auditory signals (15.2.2).  E.g. auditory signals are distinct from other auditory signals (15.2.2). |
| Avoiding false alarms |  |  | check-mark-13x13-th.png (100×100)  E.g. To have both (1) generate alarm signals in response to alarm conditions and (2) never generate alarm signals when alarm conditions do not exist (15.2.5). |
| Communicating alarm conditions |  |  | check-mark-13x13-th.png (100×100) |
| Delays | check-mark-13x13-th.png (100×100) |  |  |
| Development |  |  | check-mark-13x13-th.png (100×100) |
| Distributed alarm systems | check-mark-13x13-th.png (100×100) |  | check-mark-13x13-th.png (100×100) |
| Human Factors |  |  | check-mark-13x13-th.png (100×100)  e.g. Effective alarm signals must be compatible with human perceptual and cognitive capabilities (chapter 15.2.1) |
| Initiation and termination of alarm conditions |  |  | check-mark-13x13-th.png (100×100) |
| Instructions for use | check-mark-13x13-th.png (100×100) |  |  |
| Monitoring |  |  | check-mark-13x13-th.png (100×100)  E.g. Alarm signals only start when alarm monitoring begins (15.2.4). |
| Reset | check-mark-13x13-th.png (100×100) |  |  |
| Security | check-mark-13x13-th.png (100×100) |  |  |
| Selecting modalities |  |  | check-mark-13x13-th.png (100×100) |
| Signals | check-mark-13x13-th.png (100×100)  E.g. The alarm system may be provided with a reminder signal (6.8.2).  E.g. The alarm signal inactivation states audio paused, alarm paused, audio off and acknowledged shall be visually indicated (marked) with the appropriate symbol (6.8.5). |  | check-mark-13x13-th.png (100×100)  E.g. With very rare exceptions, an alarm system should always provide redundant alarm signals (chapter 15.2.1).  E.g. Clearly communicate the appropriate degree of urgency (15.2.2).  E.g. Minimize confusion when multiple simultaneous alarm conditions (and alarm signals) exist (15.2.2). |
| Testing |  |  | check-mark-13x13-th.png (100×100) |
| Verbal signals | check-mark-13x13-th.png (100×100) |  |  |
| Verification |  |  | check-mark-13x13-th.png (100×100)  E.g. Using first audible tone then visual alarm signal (15.2.3). |
| Visual signals | check-mark-13x13-th.png (100×100)  E.g. Alarm systems shall generate visual alarm signals to indicate the presence of alarm conditions, their priority and each specific alarm condition (6.3.2.1). |  | check-mark-13x13-th.png (100×100) |
| Machine learning | Algorithm |  |  | check-mark-13x13-th.png (100×100)  I.e. When possible, alarm  systems should be designed to identify alarm conditions on the basis of data from multiple parameters or from  multiple devices (15.4.4) |
| Instructions for use | check-mark-13x13-th.png (100×100)  I.e. Every effort should be made in designing equipment to integrate alarm systems into a coordinated system, minimizing the total number of alarm signals to which an operator needs to respond. This is important as multiple alarm conditions can generate alarm signals when one problem occurs (6.2). |  |  |
| Alarm configuration |  |  |  | check-mark-13x13-th.png (100×100)  I.e. It is permissible to disable alarm signals before the device is connected to a patient (when any alarm signal is an unnecessary distraction) and after a user who is always present at the device is alerted (15.3.8.1) |